SHIRT BUTTON-SIZED MICROTURBOJET ENGINES

Presented by

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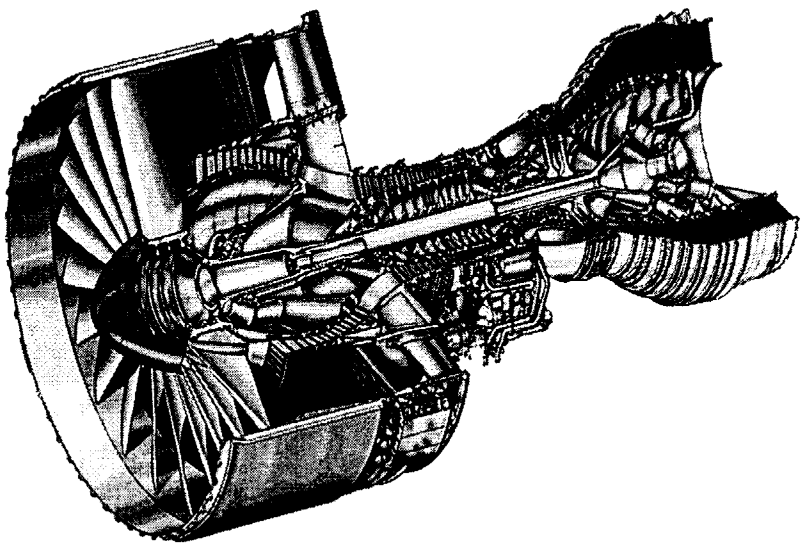
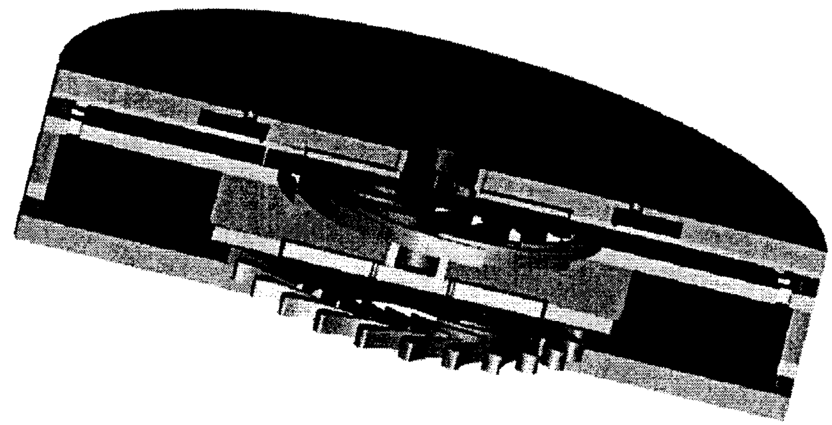
"MACRO" vs. "MICRO" GAS TURBINES

"MACRO"



"MICRO"



10,000 parts

Inlet dia = 2.8 m

Airflow = 1100 kg/sec

Weight = 10 tons

Thrust = 400,000 Nt (50 MW)

Price ~ $30/Nt

2 parts

Inlet dia = 2 mm

Airflow = 0.4 g/sec

Weight = 1 gram

Thrust = 0.1–0.2 Nt (10–30 watts)

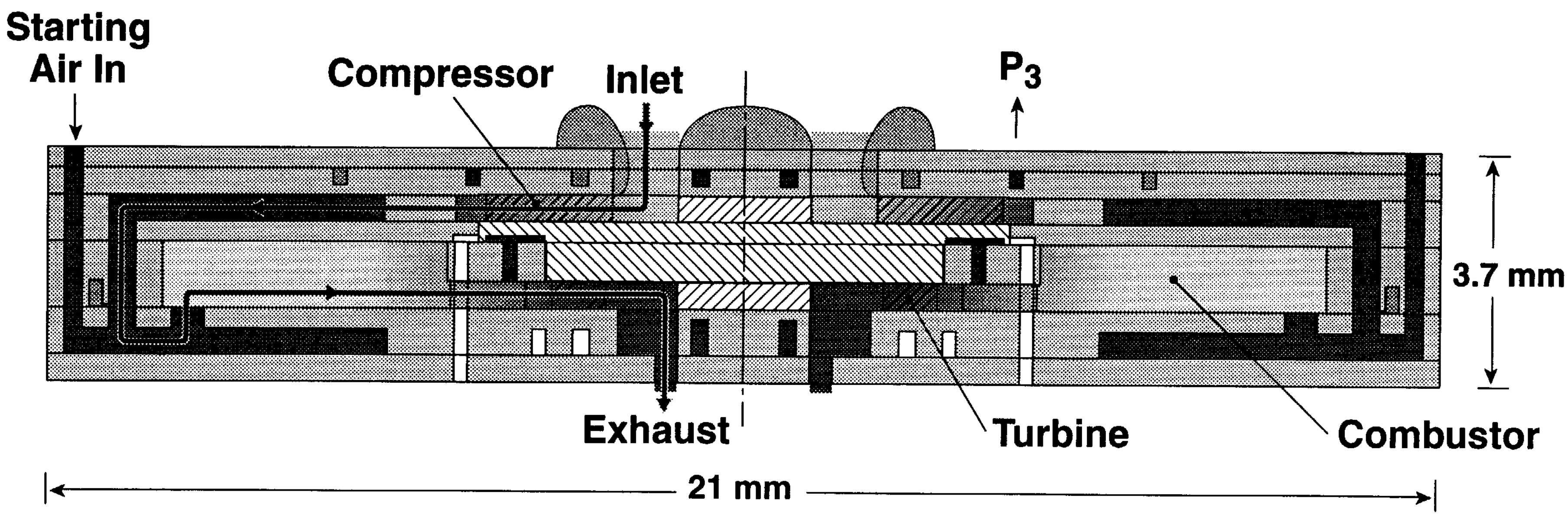
HIGH POWER DENSITY THERMODYNAMIC CYCLES
– Physical Requirements are Invariant With Size –

- High peak cycle temperatures (1200 ~ 1700°K)
  - High temperature materials
- High peripheral speeds (400 – 600 m/s), thus
  [Fluid & electric power density $\propto$ (Tip speed)^2 $\propto$ Stress]
  - Highly stressed rotating parts (100's MPa)
- Low friction bearings
- Reasonable component efficiencies
  - Close tolerances (1 μm)

μENGINES ARE NOT SCALED–DOWN BIG ENGINES

Physics Intrinsic to Small Devices	Current Technology Limits
Fluid viscous effects up	2–D “extruded” shapes
Surface area to volume high	Etching depth & aspect ratio
Short heat conduction paths	Number of layers (~10+)
Chemical reaction times const.	Most fab tech applies to Si
Many materials are stronger	Assembly, packaging, integration

H_2 DEMO ENGINE
– Silicon, Cooled Turbine –



Thrust = 11 g

Fuel burn = 16 g/hr

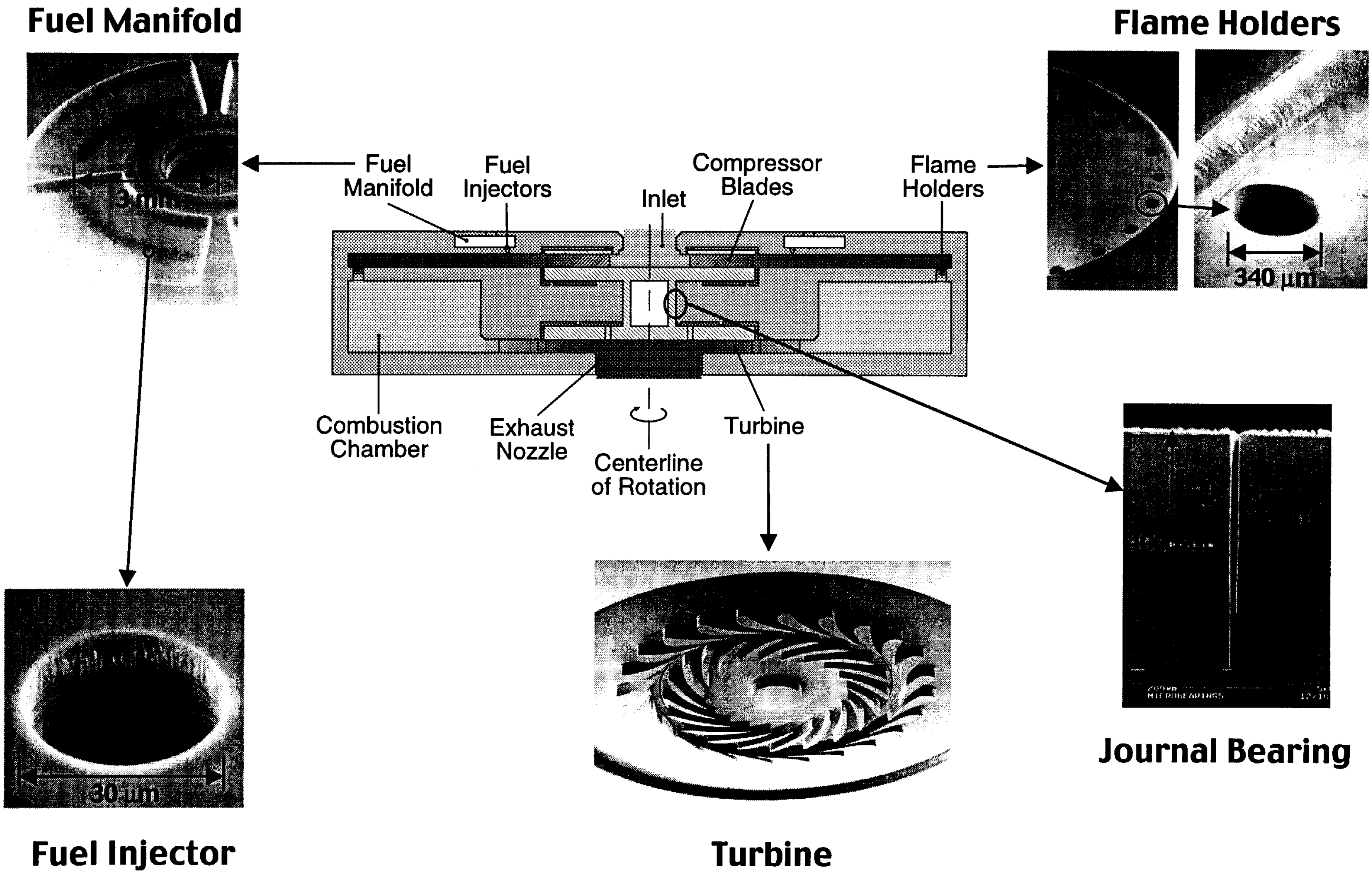
Engine weight = 1 gram

Turbine inlet temp = 1600°K (2421 °F)

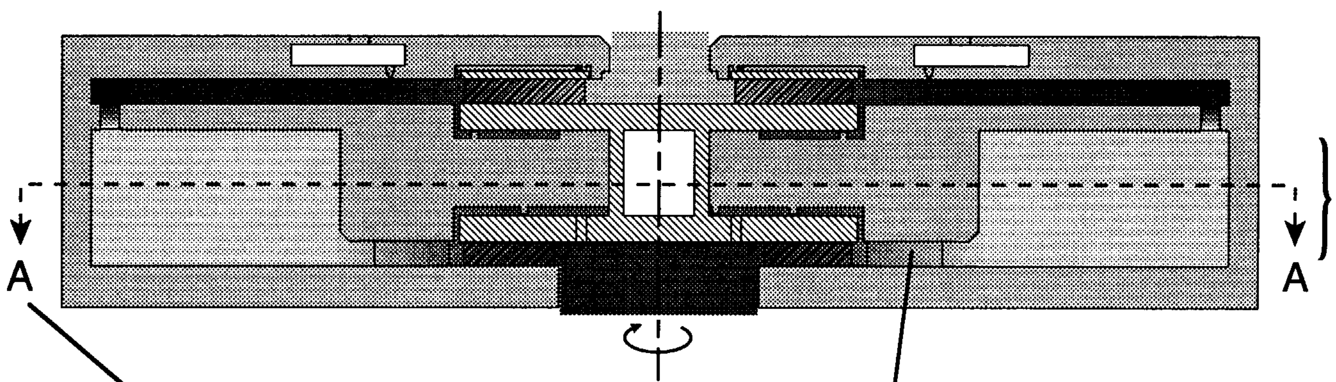
Rotor speed = 1.2×10^6 RPM

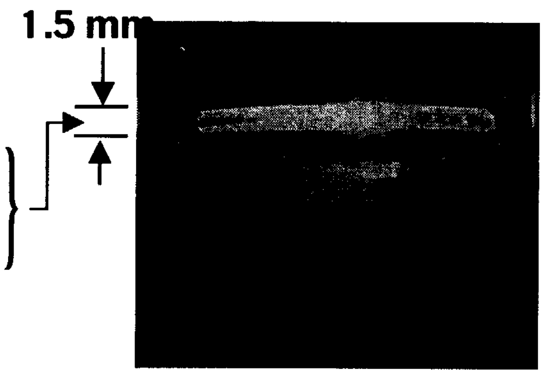
Exhaust gas temp = 970°C

MICROENGINE FABRICATION DETAILS



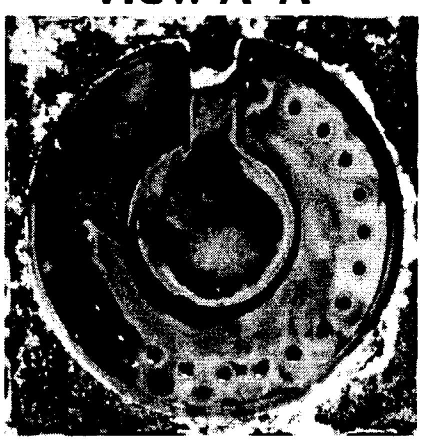
MICROCOMBUSTOR MECHANICAL INTEGRITY



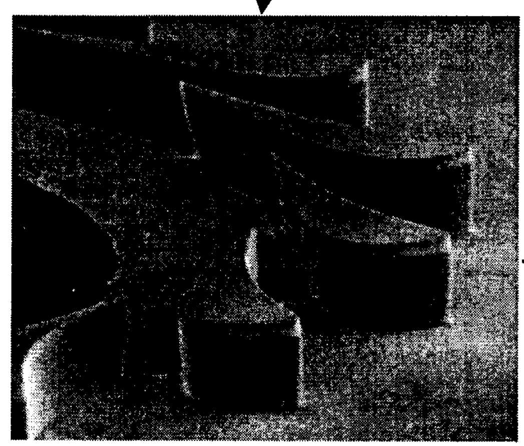


Operation at 1600°K

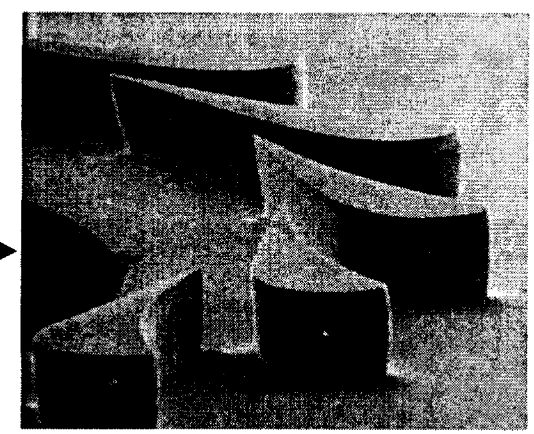
View A-A



Combustor After
15 hrs at 1800K

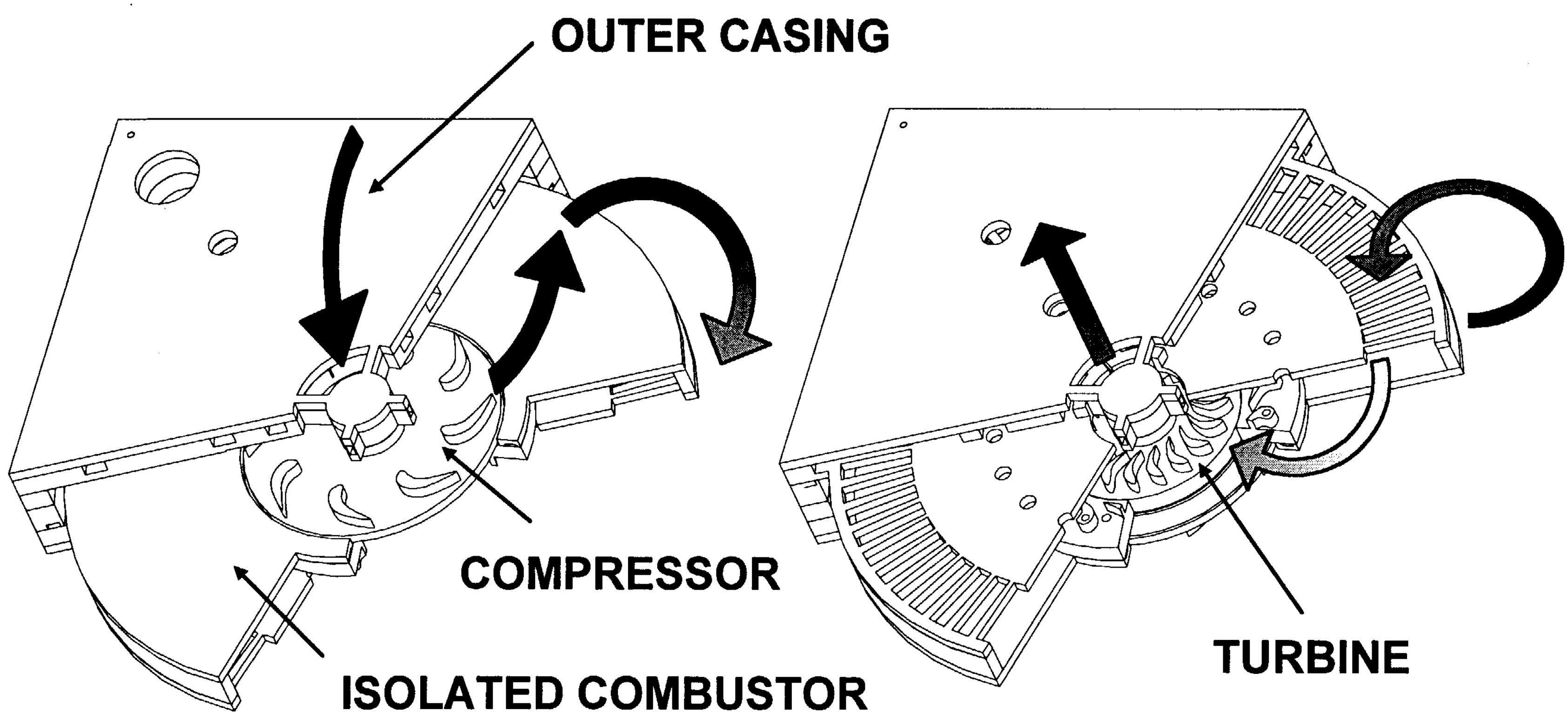


Turbine Vanes New



After 5 hrs at 1600K
Gas Temperature

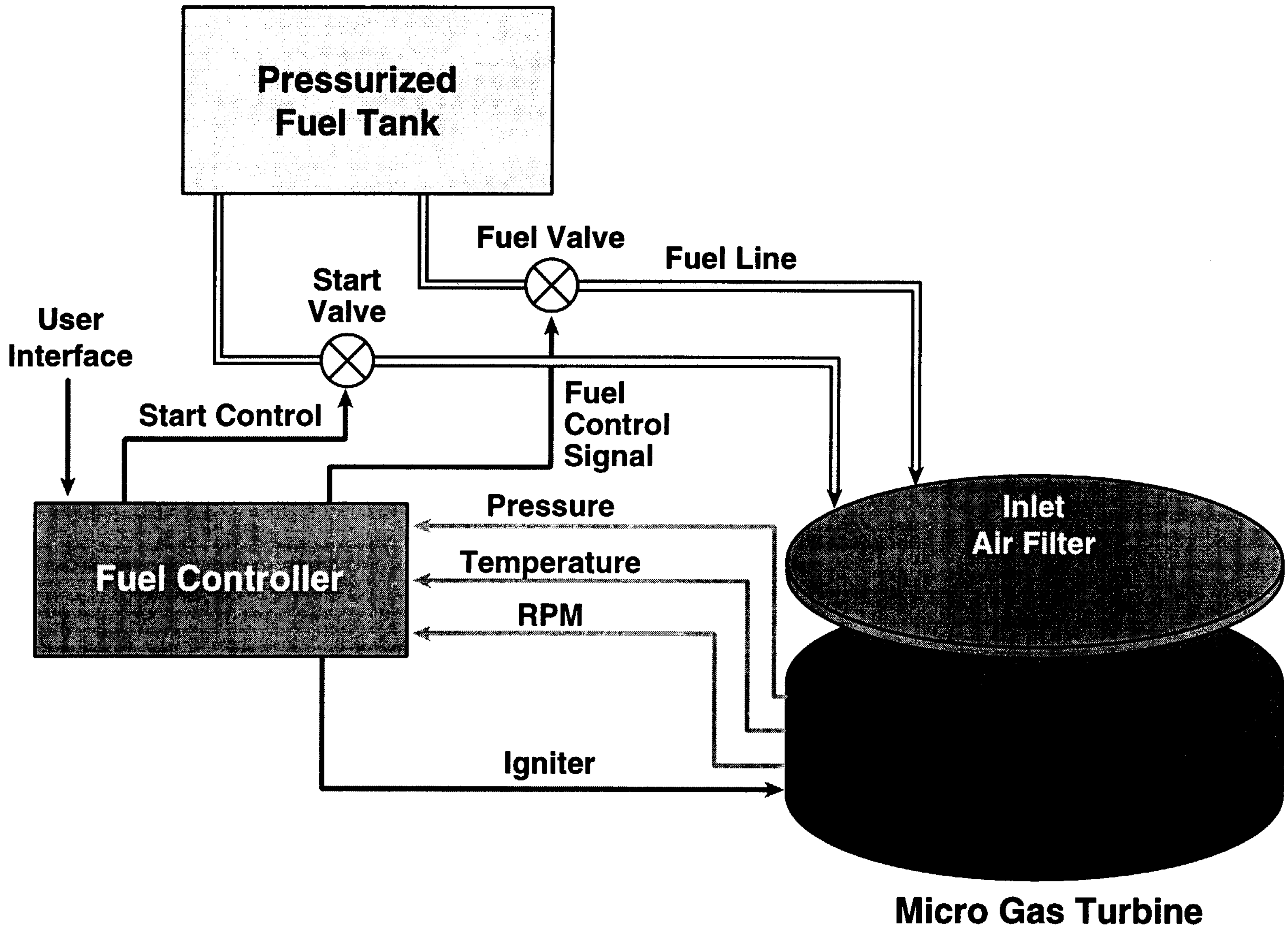
3D CUTAWAY OF DEMO ENGINE



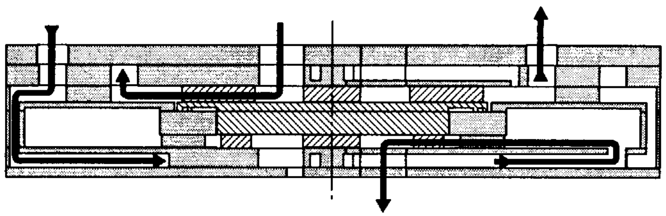
LOOKING AFT

LOOKING FORWARD

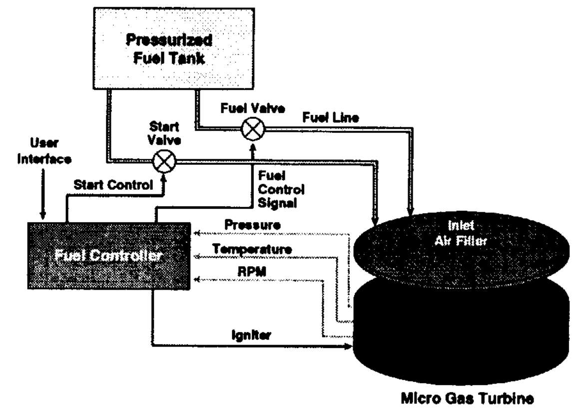
AUXILIARY SYSTEMS AND COMPONENTS



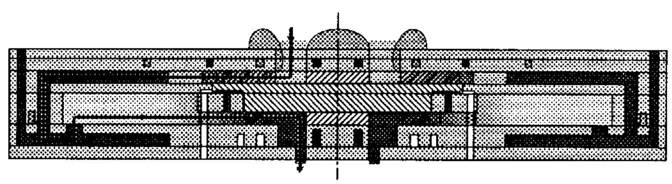
MICRO GAS TURBINE ENGINE PROGRAM PLAN



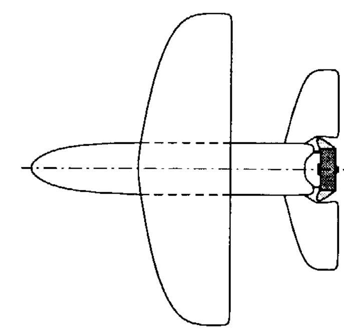
Micro rig testing in 1st qtr '99



First flight turbojet to test by 1st qtr '01



Demo H_2 engine running by 1st qtr '00



Flight tests by 2nd qtr '01

CY 1999 CY 2000 CY 2001